



Dredging Research Technical Notes



Simulation of Wave Height, Period, and Direction Time Series

Purpose

This technical note describes a procedure for generating simulated time sequences of wave height, period, and direction data corresponding to specific locations. The technique uses a finite-length wave record to compute a matrix of coefficient multipliers that can be used to generate arbitrarily long time sequences of simulated wave data which preserve the primary statistical properties of the finite data set. The procedure was developed for simulating the 20-year Wave Information Study (WIS) hindcast data base, but can be applied to any appropriate data sequence.

Background

The goal of the Numerical Simulation Techniques for Evaluating Long-Term Fate and Stability of Dredged Material Placed in Open Water work unit is to provide a simulation technique for determining how a specified dredged material mound behaves over time. The methodology is intended for site-designation investigations and is based on long-term sediment transport simulations using local hydrodynamic boundary condition input data. The intended use of the program is to provide a systematic and quantifiable approach to analyzing disposal site stability based on local environmental conditions. If material is eroded from a mound and transported away from the designated disposal site, the site is classified as dispersive. For locations predominated by strong wave and current regimes, sediment transport calculations based on averaged wave and current data may easily show the site to be dispersive; however, if the local environmental conditions are not severe, it may take months or years before significant amounts of sediment are transported from the disposal site. The ability to identify these long-term dispersive sites is especially important because the eroded material could be transported into environmentally sensitive areas. Long-term dispersion investigations require knowledge of the local wave climate and current field at the site.

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The approach selected for disposal site analysis is a numerically based sediment transport prediction scheme using long-term local boundary conditions as input. These conditions represent those forcings that entrain and transport sediment, including waves, tides, and storms. In many cases, these data are not available or are incomplete or too short in duration for long-term predictions. To satisfy the ultimate goals of the work unit, the intermediate goal of simulating realistic boundary conditions for specific locations was developed. This technical note addresses the generation of arbitrarily long time sequences of ocean wave data corresponding to specific locations. Subsequent technical notes will address additional components of the current field.

Additional Information

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Introduction

Unlike astronomical tides that can be determined with great accuracy, waves cannot be precisely predicted. A viable approach for generating realistic wave field boundary conditions is to develop a wave simulation procedure that generates waves statistically similar to those known to occur at the site, that is, preserving seasonality, directionality, distribution, sequencing, and other characteristics. A boundary condition database is obtained by simulating an existing database from which the statistical parameters describing the intercorrelations of wave field parameters can be computed (Borgman and Scheffner 1991 and Scheffner and Borgman 1992). This procedure is somewhat analogous to the computation of harmonic constituents for a tidal record. The 20-year WIS database (Corson, Resio, and Vincent 1980 and Resio, Vincent, and Corson 1982) was selected as the source of wave parameter statistics, from which a matrix of multipliers is obtained that can then be used to generate time series of wave data which emulate the WIS hindcasts. The advantage of the procedure is that a finite length of data can be used to generate an infinitely long data series which is statistically similar to the original record but exhibits normal variations about its mean.

The simulation technique had to meet two criteria for simulating time sequences of wave data based on finite-length wave records. The synthetic record has to be realistic with respect to the statistical properties of the WIS database, and the methodology has to be computationally feasible with respect to both computer memory and computational speed. Although the intent of the simulation capability is to provide times series input to the Long-Term FATE model LTFATE, the generated data can be used for any application requiring wave data. The following paragraphs

describe the methodology required to generate site-specific wave field time series.

Sequence of Computations

In order to generate arbitrarily long time sequences of simulated wave data which preserve the primary statistical properties of the WIS data, two programs must be run. First, the Height, Period, and Direction PRE-processor (HPDPRE) is run one time to produce a data summary. The data summary produced by the preprocessor can be re-used many times (Figure 1), with new seed numbers each time, to obtain alternate simulations with the program Height, Period, and Direction SIMulation (HPDSIM). Both programs can be run on a top-line 386 personal computer with extended memory. This is possible because both the preprocessor HPDPRE and the simulator HPDSIM are optimized to work with frequency-domain methods and other "fast" algorithms. Emphasis has been placed on making the simulation program work rapidly because it will be run and rerun to obtain many simulated sets of wave conditions. Extended memory is not required to run HPDSIM.

Example Application

The WIS station selected for demonstrating the capability of the simulation package is the Phase II Gulf of Mexico Station 27 (Hubertz and

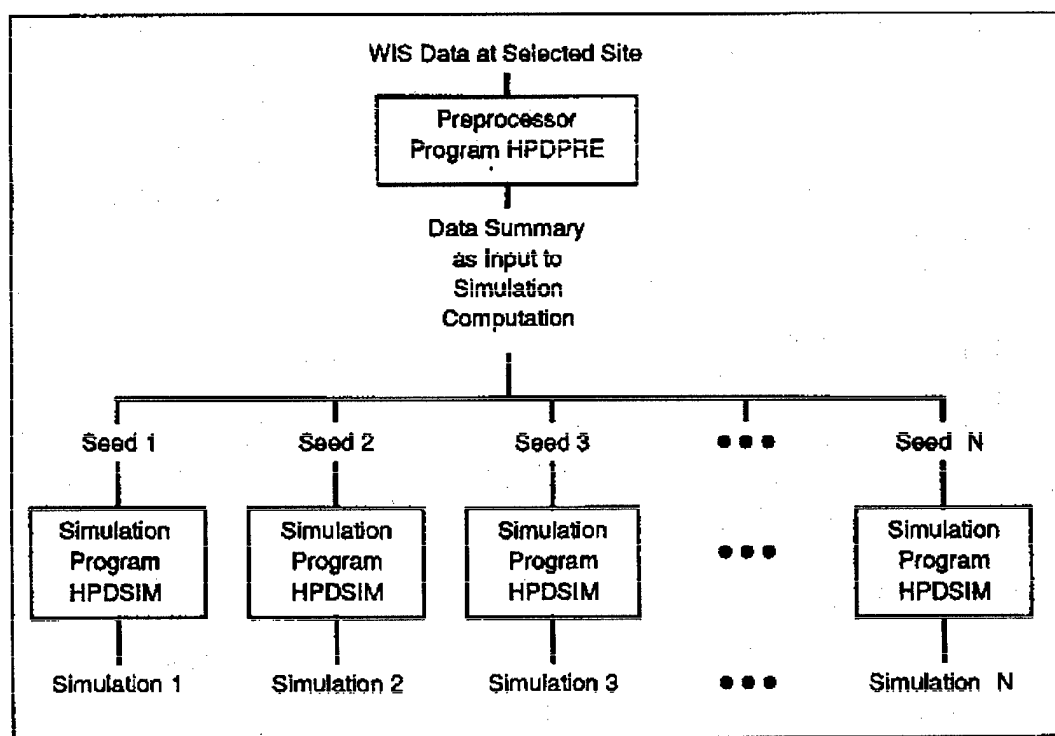


Figure 1. Flow diagram for creating multiple simulations of WIS data

Brooks 1989), located just outside the entrance to Mobile Bay, Alabama, shown in Figure 2. The simulated example used is a generated synthetic data series for September 1956 through June 1958, with starting random seed of 67676767 and is indexed as 1957. Summary plots of the entire year of simulated and of WIS time series for height, period, and direction are shown in Figures 3 and 4. Tables 1 and 2 give the computed values of maximum, minimum, average, and standard deviation for wave heights and periods. The comparisons shown indicate that the simulated and WIS data are similar with respect to both magnitudes and temporal trends, although expected differences between the two can be seen.

A more descriptive comparison of the simulated data to the WIS data can be seen through percent probability histograms that visually indicate the percent of observations in the data series that fall within specified limits, for example, the percentage of wave height observations between 1.0 and 1.1 m. Selected bands for the histograms were 0.1-m increments for

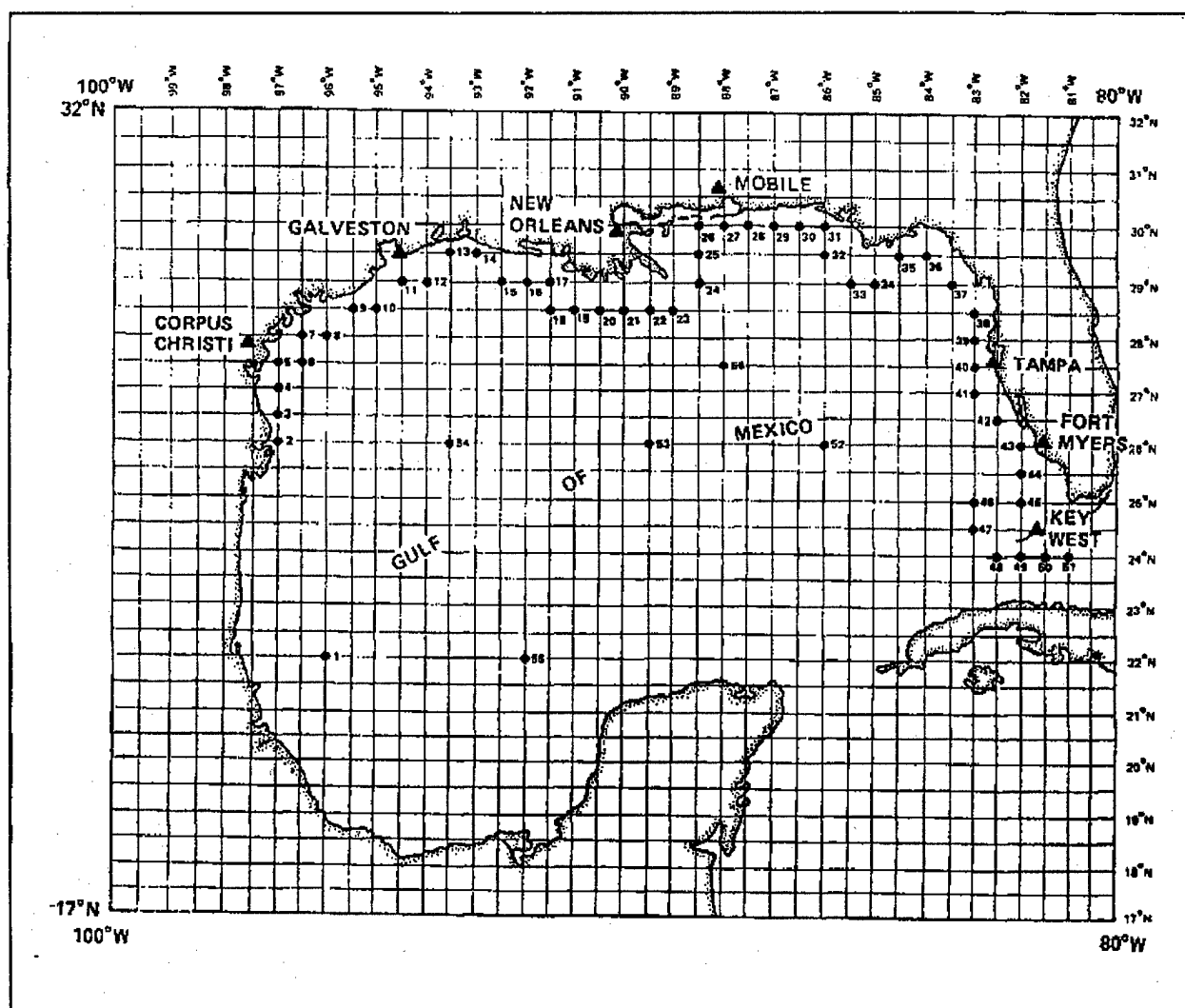


Figure 2. Location map for WIS Station 27

Table 1. Wave Height Comparisons for 1957

Month	Simulated Wave Height, m				WIS Wave Height, m			
	Max	Min	Ave	SD	Max	Min	Ave	SD
Jan	2.30	0.50	1.38	0.36	2.20	0.40	1.20	0.40
Feb	3.03	0.70	1.37	0.41	2.20	0.40	1.17	0.36
Mar	2.47	0.70	1.27	0.33	2.20	0.50	1.17	0.32
Apr	1.77	0.49	1.03	0.23	3.40	0.80	1.34	0.48
May	2.19	0.40	1.00	0.29	2.00	0.40	0.95	0.33
Jun	1.10	0.30	0.70	0.22	2.90	0.30	1.00	0.46
Jul	1.12	0.40	0.71	0.19	1.10	0.30	0.65	0.23
Aug	1.66	0.22	0.72	0.25	2.40	0.30	0.91	0.36
Sep	3.85	0.40	1.10	0.43	3.30	0.40	1.12	0.46
Oct	2.36	0.50	1.18	0.35	2.70	0.50	1.27	0.50
Nov	2.10	0.70	1.27	0.29	2.90	0.40	1.40	0.59
Dec	2.87	0.29	1.34	0.44	2.90	0.50	1.35	0.45
Jan-Dec	3.85	0.22	1.09	0.41	3.40	0.30	1.12	0.47

Table 2. Wave Period Comparisons for 1957

Month	Simulated Wave Period, sec				WIS Wave Period, sec			
	Max	Min	Ave	SD	Max	Min	Ave	SD
Jan	7.70	4.30	5.63	0.84	7.70	2.40	5.47	1.01
Feb	8.30	4.50	5.72	0.77	7.70	2.00	5.48	1.07
Mar	7.70	3.44	5.67	0.78	7.70	3.20	5.62	0.79
Apr	6.70	3.22	5.16	0.64	9.10	4.50	6.02	1.05
May	7.44	2.72	5.20	0.80	7.70	2.60	5.20	1.02
Jun	6.49	2.35	4.71	0.83	8.30	2.60	5.35	1.09
Jul	5.60	2.80	4.64	0.47	6.20	2.80	4.80	0.59
Aug	6.20	1.70	4.39	0.81	8.30	2.00	4.81	1.03
Sep	7.70	3.60	5.29	0.86	10.00	3.40	5.63	0.46
Oct	7.99	3.87	5.46	0.90	9.10	3.00	5.36	1.27
Nov	7.70	4.14	5.48	0.67	9.10	3.50	5.83	1.22
Dec	7.83	1.24	5.47	1.02	9.10	3.60	5.81	0.92
Jan-Dec	8.30	1.24	5.23	0.90	10.00	2.00	5.45	1.08

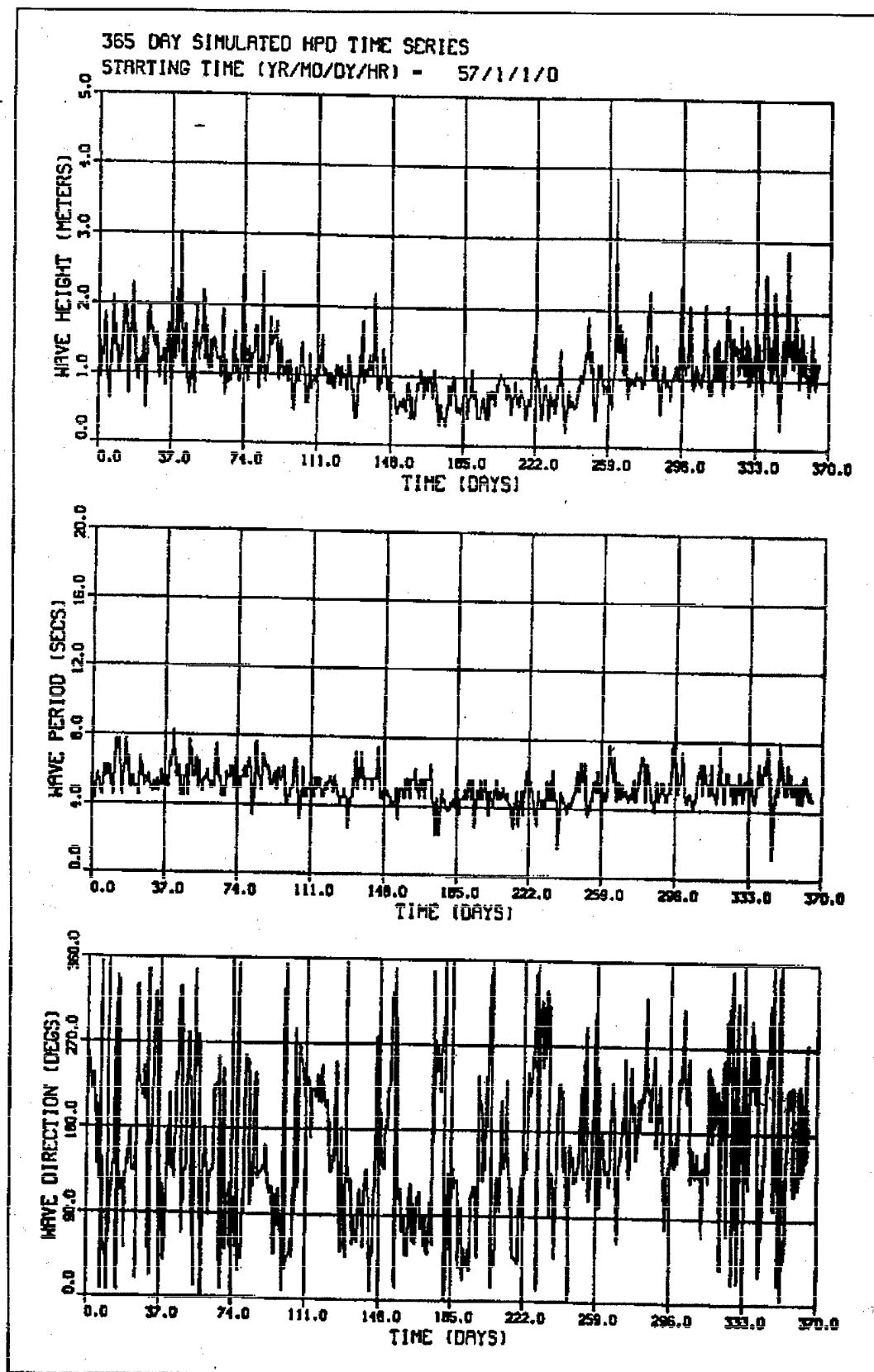


Figure 3. Simulated wave height, period, and direction for 1957

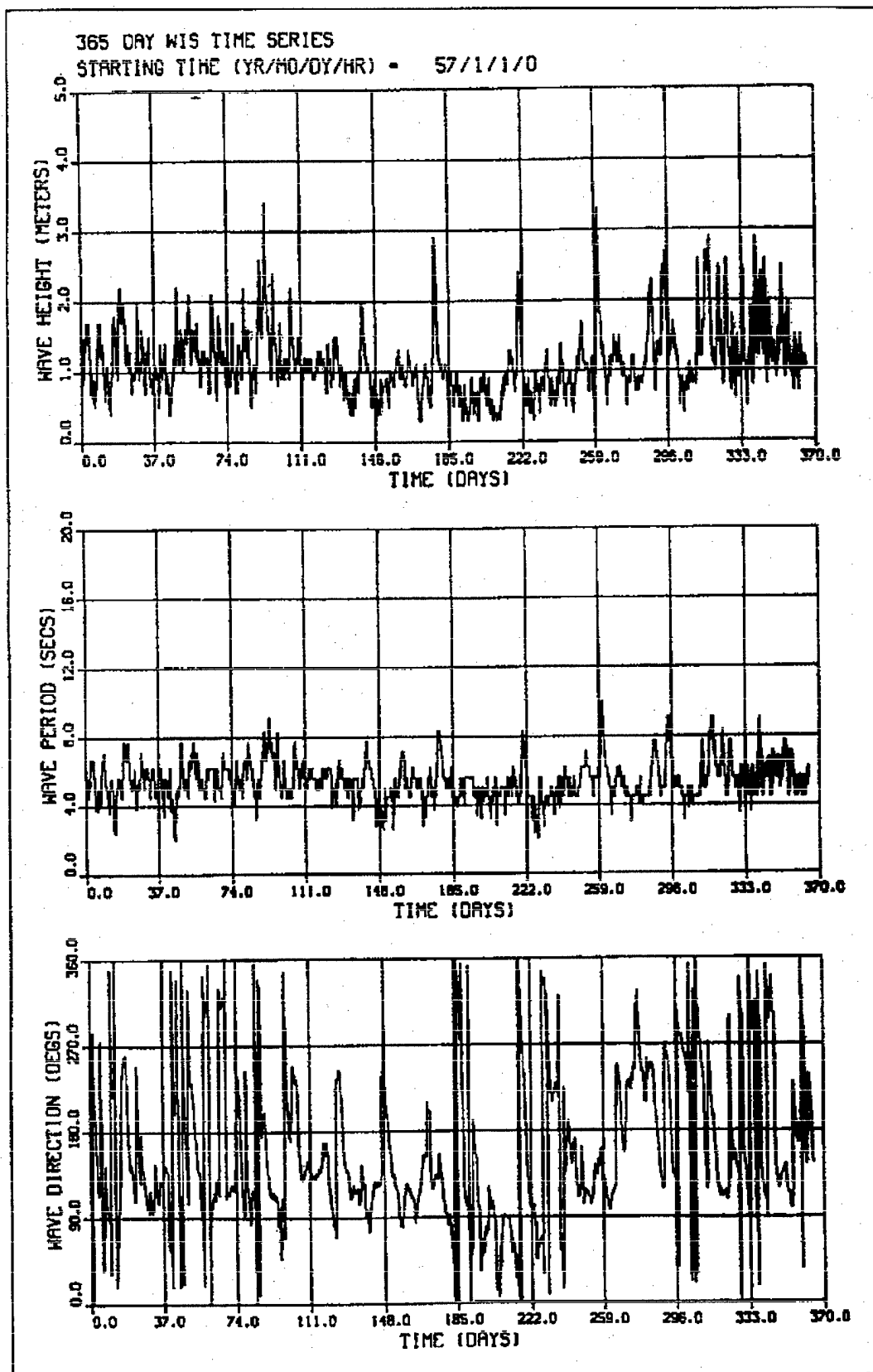


Figure 4. WIS wave height, period, and direction for 1957

wave heights, 0.5 sec for period, and 10.0 deg* for direction. These bands can be computed for both the simulated data series and the WIS data series and overlaid to provide a visual comparison of both data sets. The period of January is shown in Figure 5 which illustrates that approximately 30 percent of the January data for both the WIS and simulated time series fall within the period band of 5.0 to 5.5 sec. The plot provides a comparison of the directionality of the data that cannot be conveyed by a single mean value. For example, Figure 5 indicates that both the WIS and simulated January data series exhibit a bimodal directionality with a slight predominance in the band from 100 to 120 deg.

The variability of the WIS database can be seen in the direction histogram plots for June 1956, 1961, and 1966, shown in Figure 6. The year of 1956 shows a bimodal distribution while 1961 and 1966 do not. Also, the predominant direction of the 1956 data is centered at approximately 90 deg, but is centered at nearly 200 deg in 1966. A similar variability in simulated data can be demonstrated by selecting different starting random number seeds. Figure 7 presents three different directional histogram plots for June 1957, each generated with a different seed. As shown, the plots reflect the same degree of variability as in the WIS data.

Summary

This statistical procedure represents an improved methodology for specifying time series boundary conditions over the use of discrete or repeated historical data series. The approach represents the stochastic equivalent of generating infinitely long tidal series from a finite number of harmonic constituents. The methodology gives the user the ability to analyze the variability of certain statistical parameters of an entire prototype database such that specific prototype data periods can be analyzed with respect to their variability about the mean conditions. The procedure can be used to generate future time series of wave data, thus avoiding the practice of selecting design data from past prototype conditions or of having to repeat fixed data series in order to compose a longer time series of data than is available. The intended purpose of the database is to generate infinitely long, realistic wave data for use as boundary conditions for predicting the long-term movement of dredged material, but the methodology is recommended for any coastal application requiring either the analysis of past time series or the generation of variable-length future time series boundary conditions.

* To convert degrees to radians, multiply by 0.01745329.

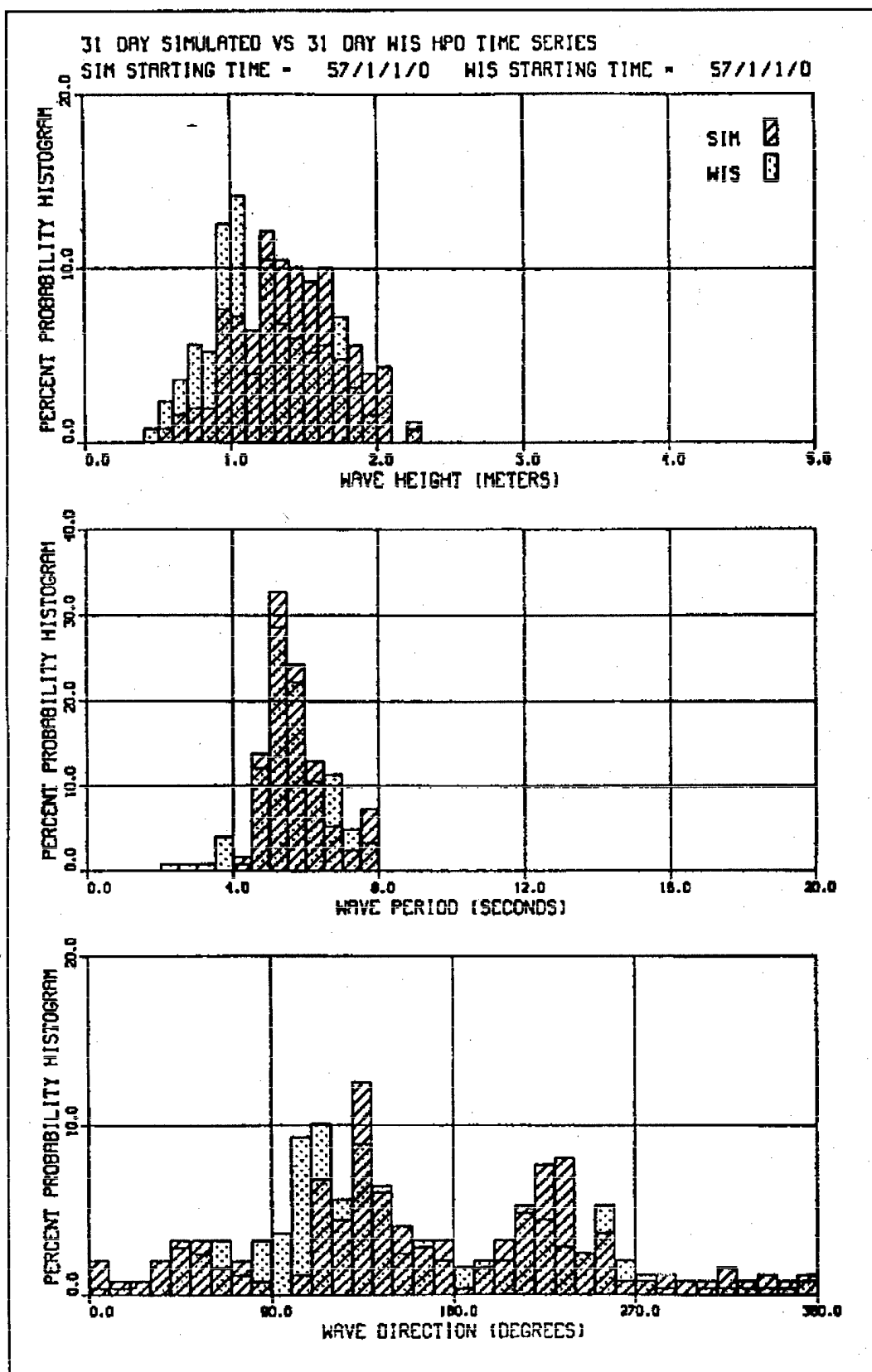


Figure 5. Probability histogram comparison for January 1957 data

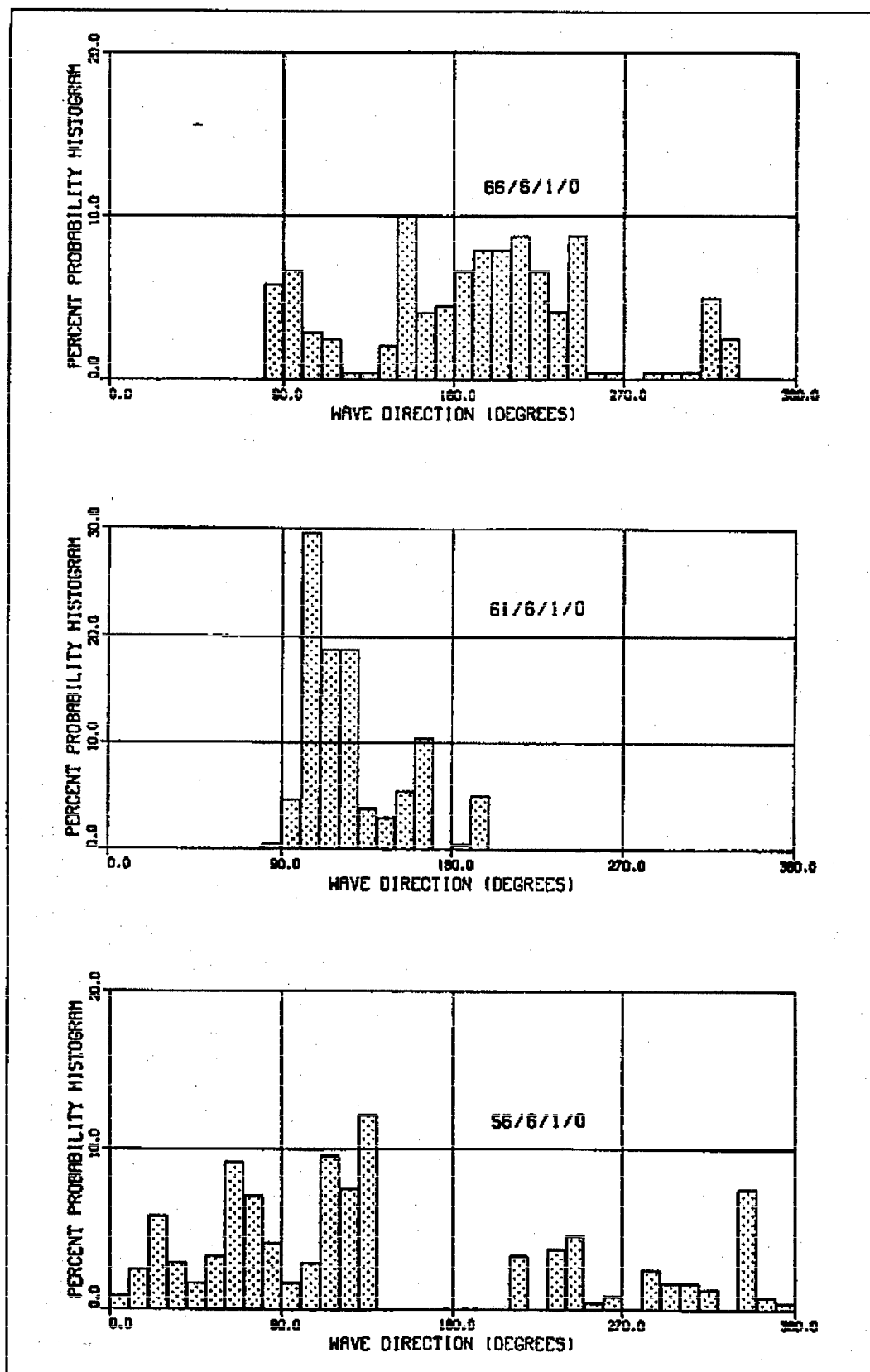


Figure 6. WIS wave direction histogram plots for June 1956, 1961, and 1966

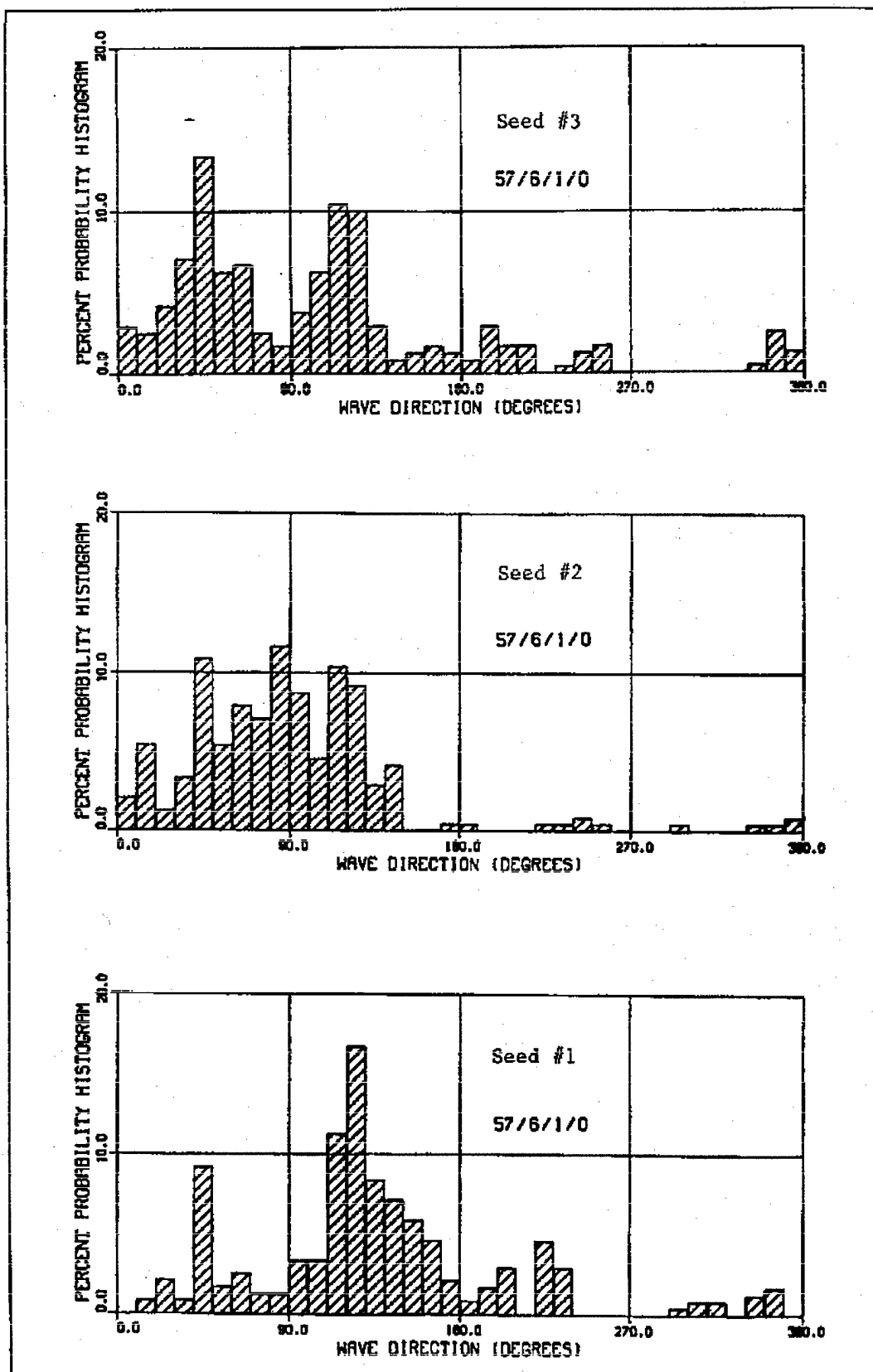


Figure 7. Three simulated wave direction histogram plots for June 1957

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